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- PASTIS -

P5.11

a fully-Bayesian tool to statistically validate exoplanets

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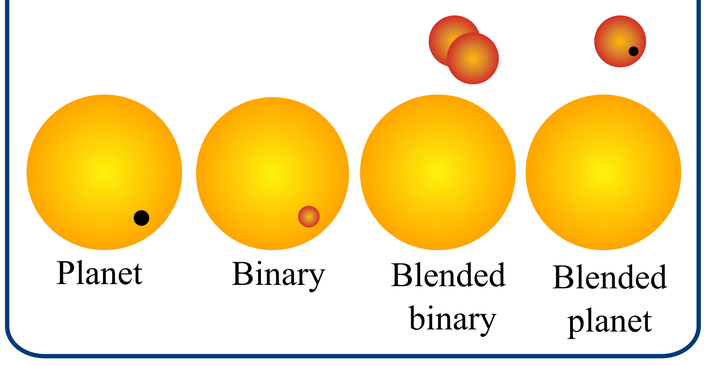
Exoplanet transit detections might be mimicked by various astrophysical scenarios (see on right for the main ones). To disentangle these sources of "noise" from exoplanet signals, a recent technique has been developed: the planet validation. It consists in calculating the propability (in the Bayesian framework) of the various scenarios. If the planet scenario is significantly the most probable, then the planet is "statistically validated".
In this context, we developped a fully-Bayesian tool, called PASTIS (Planet Analysis and Small Transit Investigation Software), to validate small planets among *CoRoT* and *Kepler* detections. **The goal of PASTIS is therefore to validate planets when other techniques** (RVs, TTVs) **failed** ! The secondary objective of PASTIS is to derive accurate parameters and robust uncertainties of the transiting systems. Below is a schematic view of the code.

Main astrophysical scenarios considered for validation



Data and constraints

Light curves:
Kepler, CoRoT, CHEOPS, TESS, PLATO, ground-based telescope, etc...

Radial velocities:
SOPHIE, HARPS, HARPS-N, etc...

Spectral Energy Distribution:
SDSS, 2MASS, WISE, etc...

External constraints:
Stellar atmospheric parameters (Teff, logg, [Fe/H]), Asteroseismic constraints (ρ), etc...

Embedded models

Light-curve model:
EBOP + beaming.

LD coefficients:
Claret & Bloemen (2011)

Stellar evolution models:
Dartmouth, Parsec, Geneva, StarEvol

Stellar atmosphere models:
ATLAS/Castelli & Kurucz, PHOENIX/BT-SETTL

Rossiter-McLaughlin effect:
Arome, SOAP-T

Stellar activity models:
SOAP/SOAP-T, Macula

Dynamical model:
Mercury6

Galactic extinction model:
Amôres & Lépine (2005)

PASTIS
Planet Analysis & Small Transit Investigation Software

MCMC

Other inputs

Prior distribution

Outputs

Posterior distribution

System parameter values and robust uncertainties

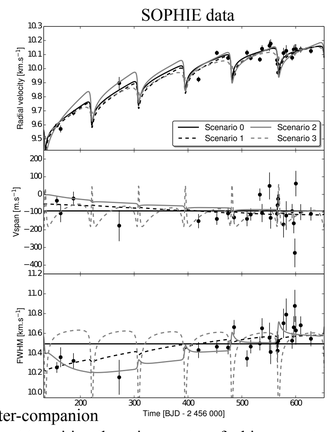
Probability of astrophysical scenario

Astrophysical objects

Planet | **Planetary systems**
Star | **Binary**
Blended star | **Multiple system** Triple, Planet in binary, etc...

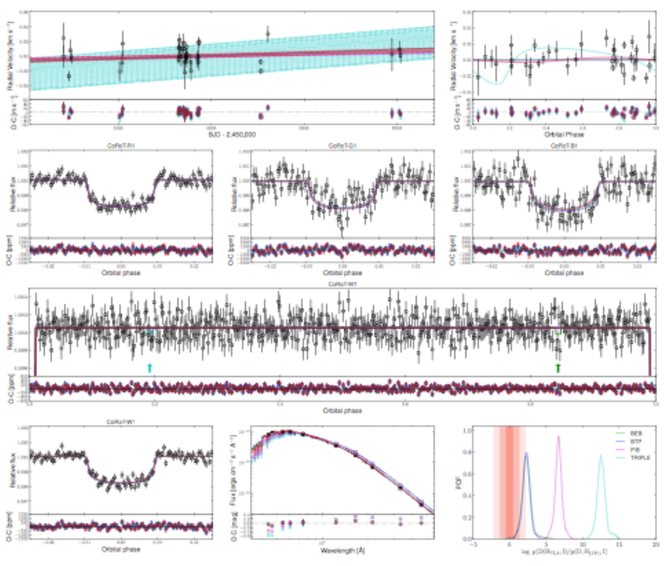
First planets validated by PASTIS

KOI-1257 (A)b:
KOI-1257 was a giant transiting planet candidate detected by *Kepler*. A radial velocity follow-up with SOPHIE revealed a long-term variation in both radial velocity and the spectral line FWHM. PASTIS was used to simulate four different scenarios to explain these variations. It concludes that the most likely scenario is a planet transiting the primary star of a binary system.



(0) outer-companion
(1) planet transiting the primary star of a binary system
(2) planet transiting the secondary star of a binary system
(3) triple system

For more information, see Santerne et al., 2014, arXiv:1406.6172

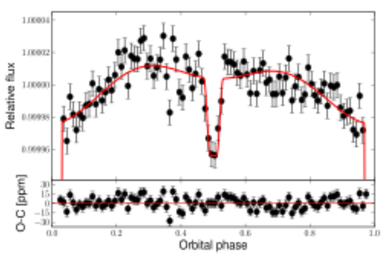


CoRoT-22 b:
CoRoT-22 was a 4.9Re candidate detected by *CoRoT*. Radial velocity follow-up with HARPS failed in establishing its planetary nature. PASTIS was used to simulate the effect of the different scenarios on the *CoRoT* coloured light-curve, HARPS data and the spectral energy distribution. By computing the probability of each scenario, the planet could be statistically validated.

For more information, see
Moutou et al., 2014, arXiv:1408.2576

Planets analysed by PASTIS

PASTIS was used to analyse the data of many *Kepler* transiting planets and brown dwarfs characterised by SOPHIE and HARPS-N (KOI-188, 192, 195, 200, 202, 205, 206, 209, 680, 686, 830, 889, 1257) as well as some *CoRoT* planets (e.g. CoRoT-7). The plot on the right is the PASTIS model of the phase curve and secondary eclipse of KOI-202 (Kepler-412).



see Deleuil et al., 2014, A&A, 564, A56

PASTIS in the context of *CHEOPS, TESS, PLATO, ESPRESSO, ...*

PASTIS is a planet-validation and planet-analysis machine that will be able to substantially contribute to upcoming space missions such as *CHEOPS*, *TESS* and *PLATO*. PASTIS is already used to define the best instrumental design of *PLATO*, to reduce false-positive detections as much as possible. PASTIS could also be used to identify the most probable false-positive scenarios of *PLATO* transiting detections and optimise the follow-up strategy.

PASTIS could also be used to *validate statistically* the planet signals that will be detected by ESPRESSO by modeling the signal of a spotted star host of planets.

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Reference paper:
Díaz, R. F., Almenara, J.-M., Santerne, A., et al., 2014, MNRAS, 441, 983